

Montana Department of Environmental Quality

Initial Operation & Maintenance Plan Burlington Northern Livingston Shop Complex Facility Livingston, Montana

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Initial Version

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Section 1

Introduction & Objectives

The BNSF Railway Company (BNSF) constructed a free product recovery system (Task D) and a bioventing system for the cleanup of petroleum-contaminated soils (Task E) at the Livingston Shop Complex Facility (Facility) in Livingston, Montana at the request of the Montana Department of Environmental Quality (DEQ). DEQ and its contractor Camp, Dresser, and McKee, Inc. (CDM) developed the initial remedial action work plan for these activities. BNSF and its contractor Kennedy/Jenks (KJ) constructed the system with DEQ's approval via a design/build approach. BNSF has requested that DEQ provide direction as to system operation. This Operation and Maintenance (O&M) Plan addresses the steps to be taken and procedures to be followed during the initial start-up and ongoing operation and maintenance of the free product recovery system and the bioventing system for the cleanup of petroleum-contaminated soils at the Facility.

The overall objective of the initial start-up of the groundwater recovery/treatment system and the bioventing system is to determine system efficiency to maximize recovery of light non-aqueous phase liquid (LNAPL) with minimal groundwater pumping and to maximize the degradation of LNAPL with bioventing. The start-up will also help determine how to phase in various components of the systems and will verify optimal operational procedures for long term operation.

Eight of the twenty multi-use wells (MUWs) are currently equipped to operate in the dual-phase pumping or LNAPL/Groundwater (GW) recovery mode. These eight wells are MUW 6, 7, 8, 12, 13, 14, 15, and 16. Three of the MUWs will operate in bioventing mode (MUW 4, 10 and 18). The MUWs to be utilized for the operation of the free product recovery and the bioventing systems are shown on Figure 1-1. The components of each of these systems are described in Section 2 of the *Task D/E, Phase I Remediation System Operations and Maintenance Manual, Burlington Northern Shop Complex, Livingston, Montana*, (Kennedy/Jenks 2007).

1.1 Changes to O&M Plan

This O&M Plan is intended to be a "living document", in that changes to the process equipment, procedures, or regulatory requirements should be incorporated into the plan as soon as possible after they occur.

Changes to the Plan may be proposed by any of the parties normally involved in Facility operations, including: BNSF, KJ, CDM, or DEQ.

Changes to this manual are to be made using the following procedure:

1. The party proposing the change will document the proposed change, the background, and the reasons in a letter or memo to the DEQ project manager. If drawings are required to implement the change, sketches to indicate specifically what is proposed must be provided.

2. The DEQ project manager will review the proposal and determine whether the change is appropriate.
3. If the change is appropriate, the DEQ project manager and DEQ's contractor will provide design drawings, if necessary, and/or other documents required to change the manual. A Revision number will be assigned and the changed pages will show the revision and date in the footer as well as on the revision page in the beginning of the plan.

Changes to equipment or operating procedures that are made on an emergency basis will be documented as soon as practical after the changes are made using the above procedure.

1.2 Project Organization and Responsibilities

The purpose of this section is to define the protocol to be applied in operating and maintaining the treatment systems.

DEQ, in its oversight role and with the assistance of its contractor, is responsible for overall project direction. All activities at the Facility must be pre-approved by DEQ via approval of work plans and manuals.

BNSF and its contractor will operate the system as directed by DEQ. BNSF and its contractor will conduct the following activities:

- Groundwater Influent and Effluent Monitoring
- Air Monitoring
- Soils Sampling
- Management of LNAPLs, Personal Protective Equipment (PPE), and Sludges
- Operation of the Water Treatment Plant (WTP)
- Maintenance of all Remediation Systems and Equipment
- Other Miscellaneous Site Services as directed by DEQ

1.3 Organization of Manual

This manual is intended to describe in detail the methods and procedures used to start up and operate the remediation systems at the site.

Section 2 describes start-up sequence, operational control parameters and instrumentation and operating criteria for the groundwater and LNAPL recovery system. Section 2 outlines: the parameters to be monitored and recorded; sampling methods; operating rules; and long term operation and optimization. Table 1-1 provides a checklist for the system start-up.

Section 3 describes start-up procedures and operating criteria for the bioventing system.

Section 2

Groundwater & LNAPL Recovery System

The groundwater/LNAPL recovery system generally consists of the following:

- MUWs
- Groundwater submersible well pumps
- Pre-filter System
- Influent Equalization/Knock Out Tank System
- GAC System
- Effluent Equalization Tank
- LNAPL Pneumatic Skimmer Pump
- LNAPL Storage System

A detailed description of the system can be found in Section 2 of the *Task D/E, Phase I Remediation System Operations and Maintenance Manual, Burlington Northern Shop Complex, Livingston, Montana*, (Kennedy/Jenks 2007).

The system withdraws both groundwater and LNAPL simultaneously from the aquifer by way of dual-phase extraction. The groundwater is pumped from each MUW causing a depression in the water table in the vicinity of the MUWs that creates a gradient inducing mobile LNAPL to flow toward the MUWs. The mobile LNAPL is then skimmed from the water surface in each MUW and then pumped to a small storage tank located in the vault of each MUW. The LNAPL ultimately is pumped to a 1,000 gallon LNAPL storage tank located adjacent to the southeast corner of the treatment building. The groundwater being pumped from each MUW is passed through a system of pre-filters and an influent equalization/knock out tank system and then treated by four carbon trains. The treated groundwater is then contained in an effluent equalization tank prior to discharge to the Yellowstone River.

The main objectives of the groundwater and LNAPL recovery system are:

- Remove free LNAPL to the maximum extent practicable
- Maximize LNAPL recovery with minimal water production
- Maintain continuous water levels to minimize invasion of water into LNAPL smear zone

The groundwater/LNAPL recovery system will begin with an initial phase of utilizing eight wells, MUW 6, 7, 8, 12, 13, 14, 15, and 16 (see Figure 1-1). The intent of this phase is to document system efficiency and produce criteria for long term

operation. This initial phase may show that future expansion of the system would be advantageous to LNAPL recovery.

2.1 Control Parameters and Instrumentation

The water treatment plant is equipped with a Programmable Logic Controller (PLC) that controls the equipment at the site. Table 2-1 lists the equipment and its instrumentation and control capabilities.

Table 2-1*: Remediation System Equipment, Control, and Instrumentation

Equipment	Control and Instrumentation
Submersible Groundwater Pumps	The pumps operate within a range of 50% to 100% (minimum speed 50%). An alarm occurs if the flow is greater than 10% below or above the flow set point. An alarm occurs if the VFD controlling the groundwater pump faults. Groundwater flow is trended and totalized for each well. Totalizing is on a daily, monthly, and project total basis. Groundwater Level is trended for each well.
LNAPL Skimmer Pump	The operator records the times during which the pumps are yielding LNAPL for each MUW. The Xitech LNAPL skimmer system includes a control box for setting skimmer pump cycle times. Each skimmer's mode of operation is documented on a weekly basis, including testing to ensure approximately 0.25 feet of LNAPL remains in each recovery well at the end of the "run" time for the cycle. The Xitech control panels also record operational run times that are noted by the operator on a weekly basis.
Influent Sump (4,250 gallon tank)	Alarms occur for high-high, high, and low levels. A separate high level switch is hardwired to a red beacon to indicate high level inside the treatment building process area.
Prefilters	Differential pressures are trended and alarm upon high differential pressure.
GAC Feed Pumps	The speed of the pump will be controlled as a closed loop level control by the Influent Sump level transmitter. The primary pump will be started when the level in the sump reaches 75% and will be stopped when the level drops to 20%. The second pump will be started if the level reaches 90%. The pumps will have a lower speed limit of 40%. Alarms occur upon pump failure. Total run time for each pump will be displayed on the SCADA screen showing the pumps.
GAC Filters (vessels)	Flow meters through the GAC filters will be trended and totalized. Differential pressures are trended and alarm upon high differential pressure.
Basket Strainer	Differential pressure is trended and alarmed.
Effluent Tank	Alarms occur for high-high, high, and low low levels.

Table 2-1 (continued)*: Remediation System Equipment, Control, and Instrumentation

Equipment	Control and Instrumentation
Effluent Pumps	The primary pump will be started when the level in the tank is above the high level switch and will be stopped when the level drops to the low level switch. The secondary pump will be started if the level rises above the high-high level switch. Alarms occur upon pump failure. Total run time for each pump will be displayed on the SCADA screen showing the pumps. Effluent flow meter will be trended and totalized.
LNAPL Oil Transfer Pump	One pump cycle pumps 2.7 gallons, which is trended and totalized for each well.
Recovered LNAPL Oil Tank	Alarms upon detection of a leak between the double walls of the tank. Alarms upon high-high level and interlocks LNAPL Oil Transfer Pumps to disable pumping to LNAPL Oil Tank. Recovered LNAPL Oil pumped into tank will be totalized as a sum of oil pumped from each well vault LNAPL Oil Tank each time LNAPL Oil Transfer Pump pumps oil.
Utilidor Sump Pump	The Utilidor sump will alarm on a high level LSH-1701 and a high high level LSHH-1701. Pump P-1700 will run in a SCADA Manual Mode only.

*Note: Data presented in Table 2-1 obtained from *Task D/E, Phase I Remediation System Operations and Maintenance Manual, Burlington Northern Shop Complex, Livingston, Montana*, (Kennedy/Jenks 2007).

The submersible groundwater pumps will be controlled by variable frequency drives (VFD) operated remotely with the PLC from the control panel in the operator's room inside the water treatment plant. The PLC allows for adjustment of groundwater discharge from each well. The discharge will be adjusted in the MUWs to maintain the groundwater level (drawdown) within the existing smear zone. The LNAPL skimmer pump cycle times will be set by the operator from the control box in the MUW vault.

The water treatment plant is designed for a maximum groundwater treatment capacity of 400 gallons per minute (gpm). A maximum of 8 MUWs will be operated at one time during start-up. Liquid levels (groundwater and LNAPL) will be monitored in the active MUWs at all times. Well pumps will be operated by adjusting discharge to optimize drawdown in each well such that the net drawdown and the resulting shape of the depressed water table across the treatment area maximize LNAPL production while minimizing groundwater production. It is anticipated that groundwater pumps will typically be operated at discharge rates between 20 and 50 gpm.

2.2 Start-up Data Collection

Start-up of the MUWs will allow for an opportunity to obtain hydraulic data that will assist in the long term operation of the remediation system. In accordance with the

overall objectives of maximizing product recovery while minimizing water production and to maintain water level drawdown within the existing smear zone associated with the LNAPL plume, the response of the aquifer to pumping will be monitored continuously during start-up and long-term operation of the remediation system. The data will be used to determine the operational parameters for pumping rate and drawdown in the MUWs and to ensure that drawdown in the pumping wells during operation is maintained within the smear zone. For reference, Table 2-2 shows the approximate elevations of the top and bottom of the smear zone for the 8 MUWs that will be operated during start-up. These elevations were determined from field observations by CDM oversight personnel during borehole drilling and from boring logs prepared by Kennedy/Jenks Consultants.

Table 2-2. Approximate Elevations for the Top and Bottom of the Smear Zone in the 8 MUWs That Will Be Operated During Start-Up

Well Designation	Elevation Top of Smear Zone (feet)	Elevation Bottom of Smear Zone (feet)
MUW-6	4472.89	4468.39
MUW-7	4473.06	4469.06
MUW-8	4473.11	4468.61
MUW-12	4473.61	4467.31
MUW-13	4474.51	4469.51
MUW-14	4475.01	4469.21
MUW-15	4475.00	4470.00
MUW-16	4475.50	4468.60

The following types of data will be collected during system start-up to support future system operations and system optimization. These data will be critical for system optimization as operations continue.

Baseline Conditions

- Monitor fluid levels in MUW wells and established monitoring well network.

Beginning at least 24 hours prior to start-up and throughout the period of start-up of the LNAPL recovery system (approximately 2 weeks), groundwater levels (drawdown) will be monitored in the observation wells shown in Figure 1-1. The list of observation wells, shown in Table 2-3, is preliminary and will be finalized after field crews can verify the existence and condition of each well. The final list may be a modification of what is presented. Well completion information for the observation well network is also listed in Table 2-3. The observation wells in the monitoring

network were selected based on their proximity to the groundwater/LNAPL extraction wells and their completion (screened) interval.

Table 2-3. Monitoring Well Network for Start-Up

Well Identification	Depth (Ft BGS)	Completion Interval (Ft BGS)
MUW-1	35	15 - 35
MUW-2	35	15 - 35
MUW-3	35.8	15.8 – 35.8
MUW-5	38	18.5 - 38
MUW-9	37.5	17.9 – 37.5
MUW-11	36.8	17.3 – 36.8
MUW-17	40	16 - 40
MUW-19	40	16 - 40
MUW-20	40	16 - 40
EX-12	33	13 - 33
EX-13	31.3	16.3 – 31.3
EX-15	30	16 - 30
HRO-14	37.7	17.7 – 37.7
HRO-15	40	20 - 40
HRO-16	38.2	18.2 – 38.2
HRO-18	37.1	17.1 – 37.1
HRO-20	27.6	17.6 – 27.6
HRO-21	26.5	16.5 – 26.5
IT-1	NA	NA
IT-2	NA	NA
IT-3	NA	NA
L-87-7	27	17 - 27
L-87-8	27	17 - 27
PMW-3	39.7	17.3 – 39.3

Note: NA = Data not available.

LNAPL Recovery

- Monitor drawdown in observation wells surrounding the MUWs. These data will be used to estimate the saturated zone radius of influence (ROI) for a given pump depth and groundwater extraction rate (discharge). The PLC can control and obtain data from 10 pressure transducers. PLC controlled pressure transducers will be placed in each of the eight MUW wells set up for groundwater and LNAPL extraction during the eight days of start-up and two additional MUWs to be identified prior to start-up. Independently operated pressure transducers will be placed in each of the remaining MUWs and all of the observation wells to obtain time-series water level data over eight-day duration of start up at a frequency of one reading every 30 seconds. Data will be downloaded from pressure transducers at least daily over the course of the start-up period for evaluation. A self contained personal digital assistant (PDA) (e.g., In-Situ RuggedReader) will be used to download fluid level data from the independently operated pressure transducers.
- Monitor product recovery rate and groundwater extraction rate (discharge) from each recovery well. These data will be used to determine the relationship at each recovery well between groundwater extraction and product recovery.

Groundwater Treatment

- Collect water samples at the influent, between carbon vessels and the effluent sample ports for VOC and total petroleum hydrocarbon (TPH) analysis, and system flow rate. These data will be used to determine the VOC and TPH mass loadings on the carbon units as well as the breakthrough curves for various contaminants.
- Collect system effluent samples for analysis of all parameters on the discharge permit list to determine if the system is operating effectively.

Specific Capacity Testing

Specific capacity data (discharge in gpm/drawdown in feet) will be measured in the initial eight MUWs to establish discharge/drawdown relationships in each well.

It is anticipated that specific capacity testing will be performed prior to start-up during the initial testing and shakedown of the groundwater & LNAPL recovery system. Prior to discharge of any treated water, MUWs will be pumped to fill all GAC vessels and water tanks in the treatment plant. There is approximately 40,000 gallons of water storage capacity in the system. Specific capacity testing will be performed during the initial filling of the tanks and vessels.

Specific capacity tests will be performed at incremental flow rates of 15, 30, and 50 gpm in each well for a period of 30 minutes at each flow rate. Groundwater levels in the pumping well will be monitored throughout the period of pumping. It is anticipated that drawdown will stabilize quickly after discharge rates are set. If the period of time required for water levels to stabilize is much shorter than 30 minutes, the time period may be decreased. Assuming 30 minute steps at the specified flow rates of 15, 30, and 50 gpm, a total of 2,850 gallons of groundwater will be pumped from each of the initial 8 MUW wells for a total of 22,800 gallons.

Specific capacity testing of the initial eight MUWs will be performed in the following order: MUW 12; MUW 8; MUW 16; MUW 6; MUW 14; MUW 7; MUW 15; and MUW 13.

Data Collection Summary

A summary of start-up data collection to be recorded during the start-up is shown in Table 2-4 below. Sample field data collection forms are provided in Appendix A.

Table 2-4: Start-up Data Collection

Start-up Data Collection	
For Initial Start-up of Recovery Systems: ~8 days	
LNAPL/GROUNDWATER SYSTEM	
	Frequency
Groundwater Pumping Rate (GPM)	5 minutes
Total Volume Groundwater Pumped (Gallons)	5 minutes
Depth to LNAPL (Feet)	Twice Daily
Depth to Water (Feet)	30 seconds
Pre-filter pressure	Hourly
Product Recovered (gals.)	counter

2.3 Start-up Sequence and Procedures

Start-up of MUWs 6, 7, 8, 12, 13, 14, 15, and 16 will be completed within a five day time frame. After each MUW groundwater and LNAPL pump is put into operation, the pumps will stay in operation. The start-up sequence for the groundwater/LNAPL will procedure in the following order:

Day 1: MUW 12

Day 2: MUW 8

Day 3: MUWs 16 and 6

Day 4: MUWs 14 and 7

Day 5: MUWs 15 and 13

MUW 12 will be put into operation and will be the only MUW operating for 24 hours in order to determine hydraulic characteristics (discharge/drawdown relationship and ROI). Subsequent MUWs will be brought on-line daily in accordance with the schedule presented above. The initial flow rate in each MUW well as it is brought on-line will be set based upon the specific capacity data obtained prior to start-up and the target drawdown. Using the discharge/drawdown relationship from MUW 12 and drawdown observed in nearby observation wells, the level at which to control the remainder of the MUWs to be brought into operation will be determined. Discharge rules in each operating MUW will be adjusted to maintain maximum capture and production of LNAPL.

Start-up of the Xitech LNAPL skimmer pumps will commence after the groundwater pump in the well has been started and adjusted to maintain the desired water level within the well. The skimmer pumps will be started and adjusted as recommended by the manufacturer, Xitech. Initial operation will generally follow the Xitech ½ rule as a product recovery guide (Xitech, 2007). After measuring the initial product thickness in the MUW, the pumping time required to remove ½ of the measured thickness within the well casing will be calculated and entered into the controller. The skimmer pump will be turned on and allowed to run for one cycle (to remove ½ of the LNAPL volume in the well casing). The pump will then be shut off and measurements will be taken to determine the amount of time required for full recovery of the LNAPL thickness. The pumping frequency can then be set in the controller by calculating the number of times a day that the pump can operate while allowing full recovery of the product thickness within the well casing prior to the pump being turned on. This general procedure will maintain some free product in the MUW while removing some free product daily from the MUW and will help maintain a steady flow of LNAPL into the recovery well.

After the initial adjustment of the Xitech controller to set the pumping time and frequency, confirmation measurements will be taken during start-up to confirm that the product has returned to full thickness prior to the programmed pump cycle initiation. If the LNAPL thickness measured prior to pumping is less than the initial full thickness, the pumping cycles per day will be reduced.

This process will be implemented during Day 1, Day 2 and Day 5 of the start-up for each of the eight MUWs. In order to optimize the LNAPL recovery at the site, future frequency for long term operation will depend on data collected during start-up.

A Start-up Checklist is shown in Table 2-5. It is recommended that a copy of the checklist be used to guide the start-up each time it is performed.

Table 2-5 Groundwater/LNAPL Start-up Checklist

Step	Action	Comment	Complete (Y/N)	Initial	Date
1.	Placement and calibration of pressure transducers in all monitoring locations	Monitoring points may change over time as the aquifer's response to pumping and the relationship between groundwater extraction and LNAPL production are better understood.			
2.	Monitor static groundwater and LNAPL conditions prior to pumping.	A minimum of 24 hours of data recorded at 15 minute intervals.			
3.	Day 1: Start up 1st of eight wells and set pumping rate to establish desired drawdown in recovery well. Continue to operate for remainder of start-up period	It should be the goal to obtain maximum LNAPL recovery while minimizing the groundwater extraction rate.			

Table 2-5 Groundwater/LNAPL Start-up Checklist

Step	Action	Comment	Complete (Y/N)	Initial	Date
4.	Monitor groundwater levels in established monitoring well network at 30 second intervals throughout start-up period.	Frequency of data recording may change as the aquifer's response to pumping and the relationship between groundwater extraction and LNAPL production are better understood			
5.	Day 2: Start up 2nd of eight wells and set pumping rate to establish desired drawdown in recovery wells. Continue to operate for remainder of start-up period				
6.	Day 3: Start up 3 rd and 4 th of eight wells and set pumping rate to establish desired drawdown in recovery wells. Continue to operate for remainder of start-up period				
7.	Day 4: Start up 5th and 6 th of eight wells and set pumping rate to establish desired drawdown in recovery wells. Continue to operate for remainder of start-up period				
8.	Day 5: Start up 7th and 8 th of eight wells and set pumping rate to establish desired drawdown in recovery wells. Continue to operate for remainder of start-up period				

A summary diagram of the groundwater and LNAPL recovery system start-up is shown in Figure 2-1.

2.4 Operating Criteria

Specific operating rules will be developed based on response of the system during the start-up period. General guidelines can be outlined in advance and are enumerated below.

- Pilot testing at the site has demonstrated that LNAPL recovery is facilitated by pumping of groundwater in order to develop a hydraulic gradient toward the recovery well. The design of the system includes a line of wells that will develop a trough on the groundwater surface that will aid in moving LNAPL toward the recovery facility. A balance must be maintained between minimizing the production of groundwater, while optimizing the LNAPL recovery. The operating

criteria at the site are complicated by the seasonal fluctuations in groundwater that occur at the facility.

Preliminary operating criteria include the following general items:

- Maintain the pumping level in the well near the lower contact of the LNAPL smear zone. Drawing water levels below this level will result in production of excess water, potentially increase the smear zone depth, and limit LNAPL production due to the increased water percentage in the LNAPL flow zone.
- Maintain an LNAPL thickness sufficient to allow continued production. This criteria will be refined during the start-up testing. This will require adjustment to the pump cycle time based on start-up data. The LNAPL pumps also need to be adjusted to minimize production of water with the LNAPL.
- Operate the groundwater pumping in a stable manner to minimize fluctuations that will impact LNAPL productivity. This will require adjustments to system operations during the high water season. This may require shutting down less productive recovery wells during the high water season to maintain the same elevation in the well, while operating within the treatment and pumping capacity of the system.
- Groundwater pumping rates will need to be adjusted to maintain a stable water level that provides a gradient toward the recovery wells.

2.5 Long Term Operation and Optimization

Long term operational criteria will be established after the start-up period and will use the data and lessons-learned from the start-up testing to optimize the recovery and treatment systems.

Section 3

Bioventing System

The bioventing system consists of the following main components:

- Vacuum Pump
- Conveyance Piping
- Air-Water Separator
- Vapor-phase GAC

A detailed description of the system can be found in Section 2 of the *Task D/E, Phase I Remediation System Operations and Maintenance Manual, Burlington Northern Shop Complex, Livingston, Montana*, (Kennedy/Jenks 2007).

3.1 Control Parameters and Instrumentation

The bioventing system is equipped with a Programmable Logic Controller (PLC) that controls the bioventing equipment. Table 3-1 shows the equipment and its instrumentation and control capabilities.

Table 3-1*: Bioventing System control and instrumentation.

Equipment	Control and Instrumentation
Bioventing Equipment in a Well Vault	Bioventing air flow and vacuum pressure are trended.
Bioventing Vacuum Blowers	Speed of the blowers will be controlled by the infeed flow setpoint. Bioventing Vacuum Blower Infeed Air Flow and Discharge Air Flow will be trended.

*Note: Data presented in Table 3-1 obtained from *Task D/E, Phase I Remediation System Operations and Maintenance Manual, Burlington Northern Shop Complex, Livingston, Montana*, (Kennedy/Jenks 2007).

3.2 Startup Data Collection

The following types of data will be collected during system startup to support future system operations and system optimization. This list is not all inclusive, as there will be many other readings/observations that will be needed to start up the system. However, many of the items below will be important for helping to optimize the system as operations continue.

Baseline Conditions

- Oxygen and carbon dioxide concentrations in all wells within 150 feet of the bioventing wells to be operated (see Figure 3-2)
- photoionization detector and flame ionization detector (PID/FID) readings at all wells within 150 feet of the bioventing wells to be operated
- Pressure readings at all wells within 150 feet of the bioventing wells to be operated

Bioventing

- Vapor extraction rate from a bioventing well, the applied vacuum at that well and the induced vacuum at wells within 150 feet of the bioventing well. These data will be used to estimate the Radius of Influence (ROI) and vapor extraction rate for a given applied vacuum.
- Perform step testing to determine the relationship between applied vacuum, ROI and vapor extraction rate. Additional monitoring/observation points may be required to determine these relationships. If the data collected during initial testing are not sufficient for determining ROI, it will be expected that additional monitoring points will be added.
- Screen bioventing well extracted vapors for volatile organic compounds (VOCs) with a PID/FID and collect vapor samples from bioventing wells for VOC/ volatile petroleum hydrocarbon (VPH) analysis. These results will be used to determine the VOC/VPH mass that is sent to the vapor treatment system.
- Measure oxygen and carbon dioxide concentrations at wells within 150 feet of the bioventing wells before and during startup. These results will be used to estimate the zone of aeration around bioventing wells, and to determine which wells may be appropriate for in situ respiration testing.

Vapor Treatment

- Collect vapor samples at the influent, between carbon vessels and the effluent sample ports for VOC and VPH analysis, and system flow rate. These data will be used to determine the VOC and VPH mass loadings on the carbon units as well as the breakthrough curves for various contaminants.
- Determine the carbon influent temperature

Data Collection Summary

A summary of start-up data collection to be recorded during the start-up is shown in Table 3-2 below. Sample field data collection forms are provided in Appendix A.

Table 3-2: Start-up Data Collection

Start-up Data Collection	
For Initial Start-up of Recovery Systems: ~8 days	
BIOVENTING SYSTEM	
Pre-Start-up Pressure (inches of water)	Frequency Once
Vapor Extraction Rate (scfm)	5 minutes
Applied Vacuum (inches of water)	5 minutes
Temperature	Twice Daily

3.3 Startup Sequence and Procedures

Startup of the bioventing system will include operation of three MUWs: MUW-4, MUW-10 and MUW-18. A startup checklist for the bioventing system is shown in Table 3-3. This checklist accompanies the procedures given below.

Pre-Startup Monitoring

Measure pressure, total VOCs (using a PID/FID instrument), oxygen, carbon dioxide, and methane (using a Landtec infrared gas analyzer or equivalent) at each monitoring well that is within 150 feet of the three bioventing wells to be operated. Each of these wells will be fitted with a valved, air-tight fitting that allows vapors to be withdrawn by the PID/FID and the Landtec and allows for connection of a pressure gage. The valves will be closed during bioventing.

Individual Well Tests

Each of the three bioventing wells will initially be operated independently to gather data concerning the ROI, extracted vapor quality and vapor extraction rate. A step test will first be performed to determine the relationships between applied vacuum, extraction rate and ROI. Next the well will be operated at a steady applied vacuum and the ROI and vapor quality will be monitored over time.

Step testing at MUW-4 will be performed first. The testing will be performed in accordance with the methods set forth in the *Bioventing Design Tool TM – User's guide* (Battelle, 1996). Three steps will be targeted, each using a higher applied vacuum. The vapor extraction rate that results from the third step will approximate the design flow of 100 scfm. The targeted flows for the three steps will be approximately 30%, 60% and 100% of the design flow. These target flows may need to be adjusted at each well depending on the applied vacuum to flow relationship that is measured.

At each step the following parameters will be measured:

- Wellhead vacuum (inches of water)
- Vapor extraction rate (standard cubic feet per minute (scfm))
- Vacuum at each monitoring well potentially within the ROI (inches of water)
- PID/FID readings of extracted vapors (ppmv)

When the step testing is complete for a given well, an extended test will be performed. It is anticipated that this test will span 1 to 2 days. The main objective is to collect all of the data that were collected during step testing over a longer period to see if any significant trends are noticed.

Multiple Well Test

Following the single well step and extended tests, all three bioventing wells will be operated together, each at the design flow of 100 scfm or other flow as determined by the single well test results. Each of the parameters list above for the step tests will be

measured for this part of the testing. Operational adjustments will be made as necessary to keep the flows from each well at the targeted rate(s). The concentration of total VOCs in the extracted vapor stream will be monitored with the PID/FID several times a day. These readings will be important in that they will document the rate of decline in VOCs in the extracted vapors as more pore volumes of vapor are removed.

A summa canister will be used to collect vapor samples from the influent line to the vapor phase GAC and from the line in between GAC vessels. These samples will be analyzed for VOCs with EPA method TO-15 and for VPH using EPA method 8015. These samples will be collected approximately weekly to quantify the decrease in contaminant concentrations and to track changes in the composition of contaminants.

Table 3-3 Bioventing Startup Checklist

Step	Action	Comment	Complete (Y/N)	Initial	Date
1.	Pre-startup pressure at MUW 4, MUW 10, MUW 18, monitoring wells within 100 ft.				
2.	Pre-startup PID readings at MUW 4, MUW 10, MUW 18, monitoring wells within 100 ft.				
3.	Pre-startup O ₂ /CO ₂ /CH ₄ readings at MUW 4, MUW 10, MUW 18, monitoring wells within 100 ft.				
4.	Single well step test wellhead vac., flow, MW vac. and PID/FID of extracted vapors				
5.	Extended single well test wellhead vac., flow, MW vac. and PID/FID of extracted vapors				
6.	Extended multiple well test wellhead vac., flow, MW vac. and PID/FID of extracted vapors and between GAC vessels				
7.	Extended multiple well test summa sample collection				

A summary diagram of the bioventing system start-up is shown in Figure 3-1.

3.4 Operating Criteria

A major operating criterion for the bioventing system is maintaining the design ROI so that the entire targeted portion of the vadose zone is aerated. Both oxygen and vacuum readings at monitoring wells within the ROI of an operating bioventing well will be used to determine the ROI. If these measurements do not indicate that the ROI is large enough, then the applied vacuum at that well will be increase until acceptable reading are recorded.

Properly placed and designed monitoring wells or points that are screened within the unsaturated vadose zone will be used to perform in situ respiration tests. The results of these tests will be used to monitor the performance of the bioventing system and to quantify the amount of contaminants that are biodegraded during bioventing.

Any existing monitoring wells that are within the ROI of any of the three operating bioventing wells will be used to perform in situ respiration tests at the end of the multiple well tests. The results will be evaluated with regard to deciding whether these monitoring wells are appropriate for subsequent respiration tests. If not, then new monitoring points that are screened only within the smear zone will be installed as necessary to monitor the performance of the entire bioventing system.

3.5 Long Term Operation and Optimization

So that bioventing may be applied to the entire phase 1 area, bioventing wells will be pulsed. The idea being that one or more pore volumes of soil vapors will be extracted resulting in the direct removal of VOCs and the aeration of the soils within the ROI of a given well. Operation at that well will then cease allowing for soil VOCs to partition into the soil vapor and the aerobic bacteria to utilize the oxygen to biodegrade contaminants. The changes in oxygen concentration in vapors within the monitoring wells adjacent to the bioventing wells will be evaluated to estimate how long bioventing must be performed to aerate the targeted soils. Also, the PID/FID reading trends will be evaluated to determine pulse duration and frequency.

The data regarding pulse frequency and duration can then be used to schedule bioventing operations at each MUW. In situ respiration testing will also be used to monitor vadose zone conditions and monitor progress towards achieving soil cleanup levels.

Section 4

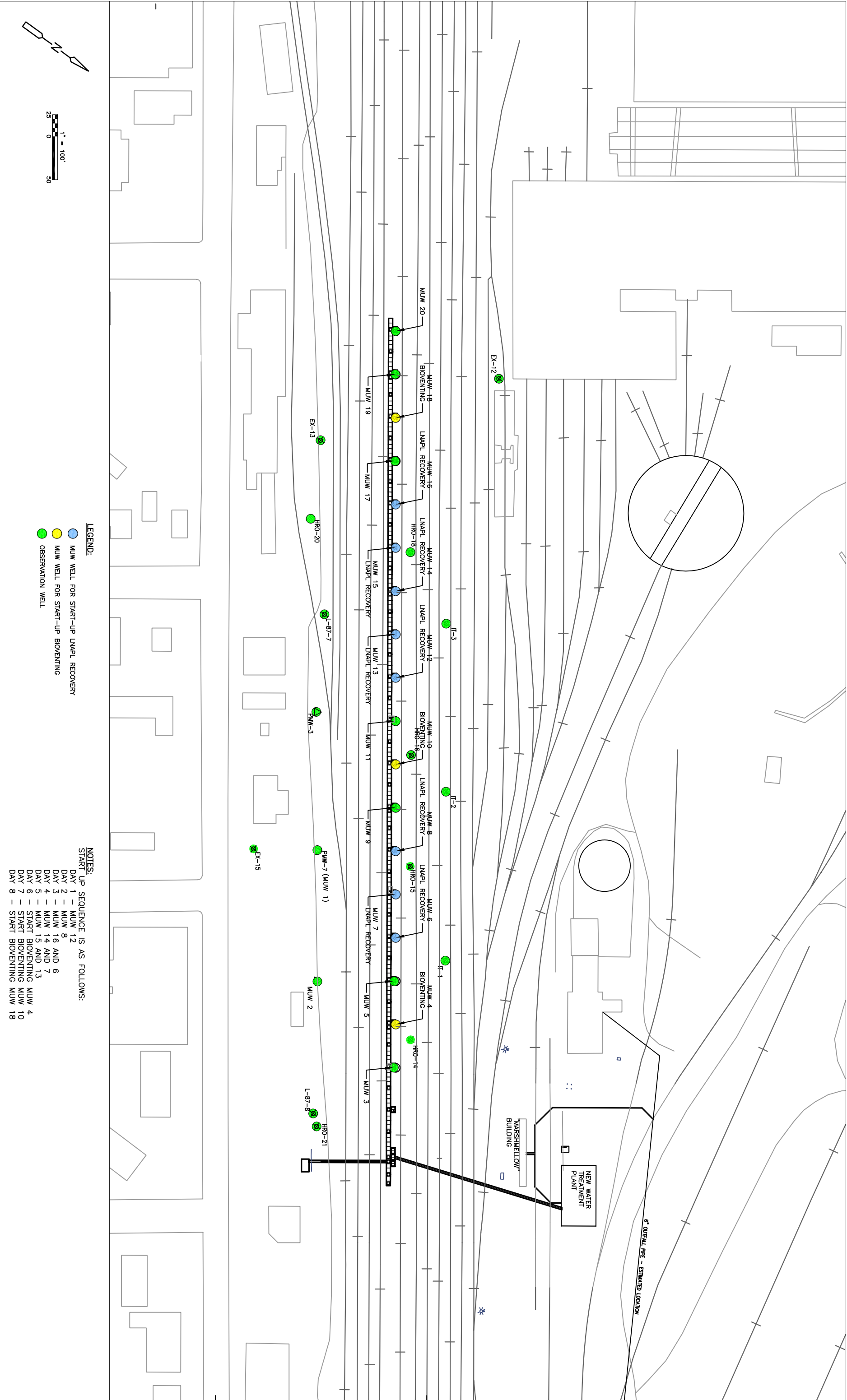
References

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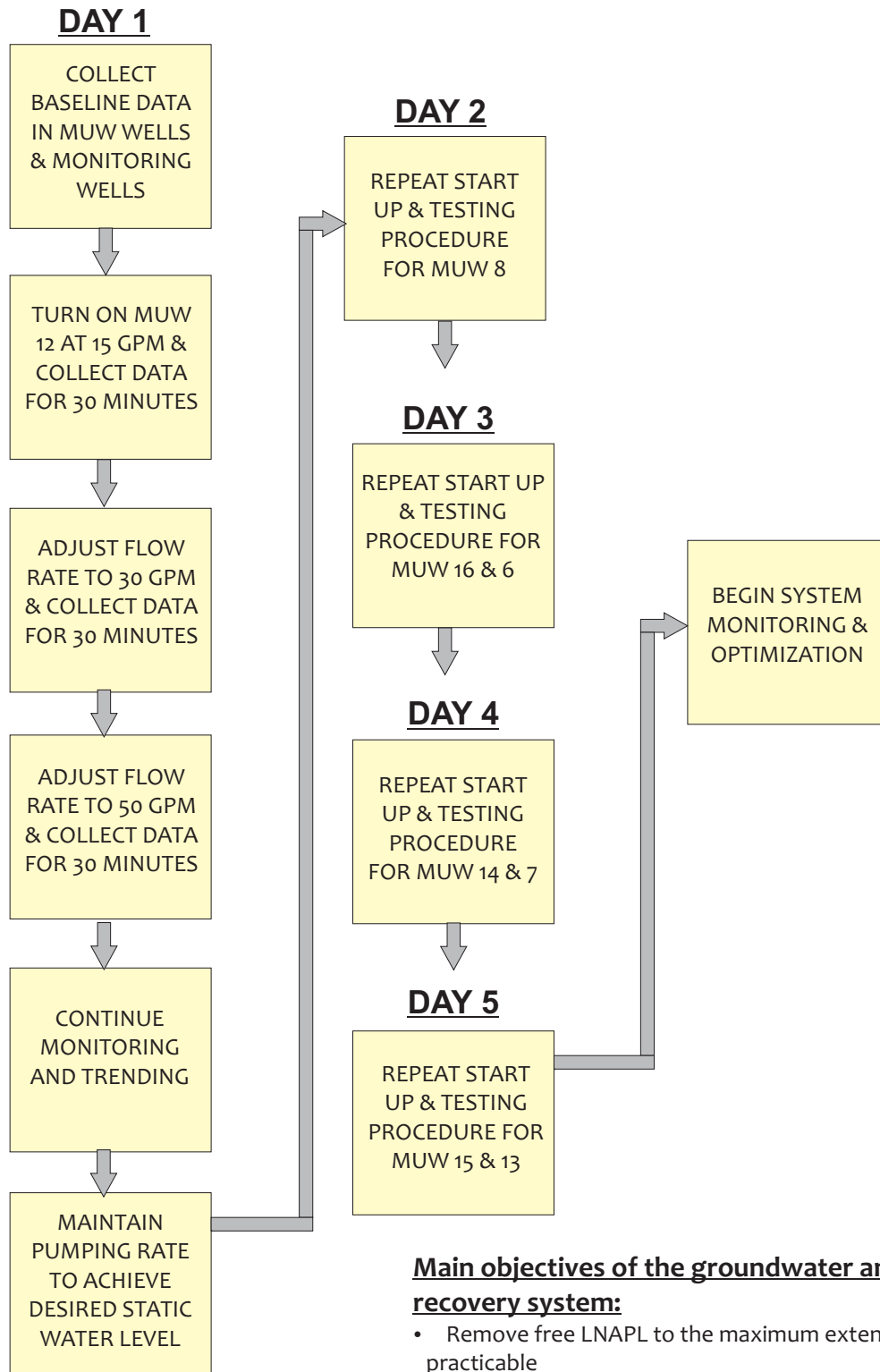
Figures



BN LIVINGSTON
LIVINGSTON, MT

Figure 1-1
Multi-Use Well (MUW) and
Observation Well Locations



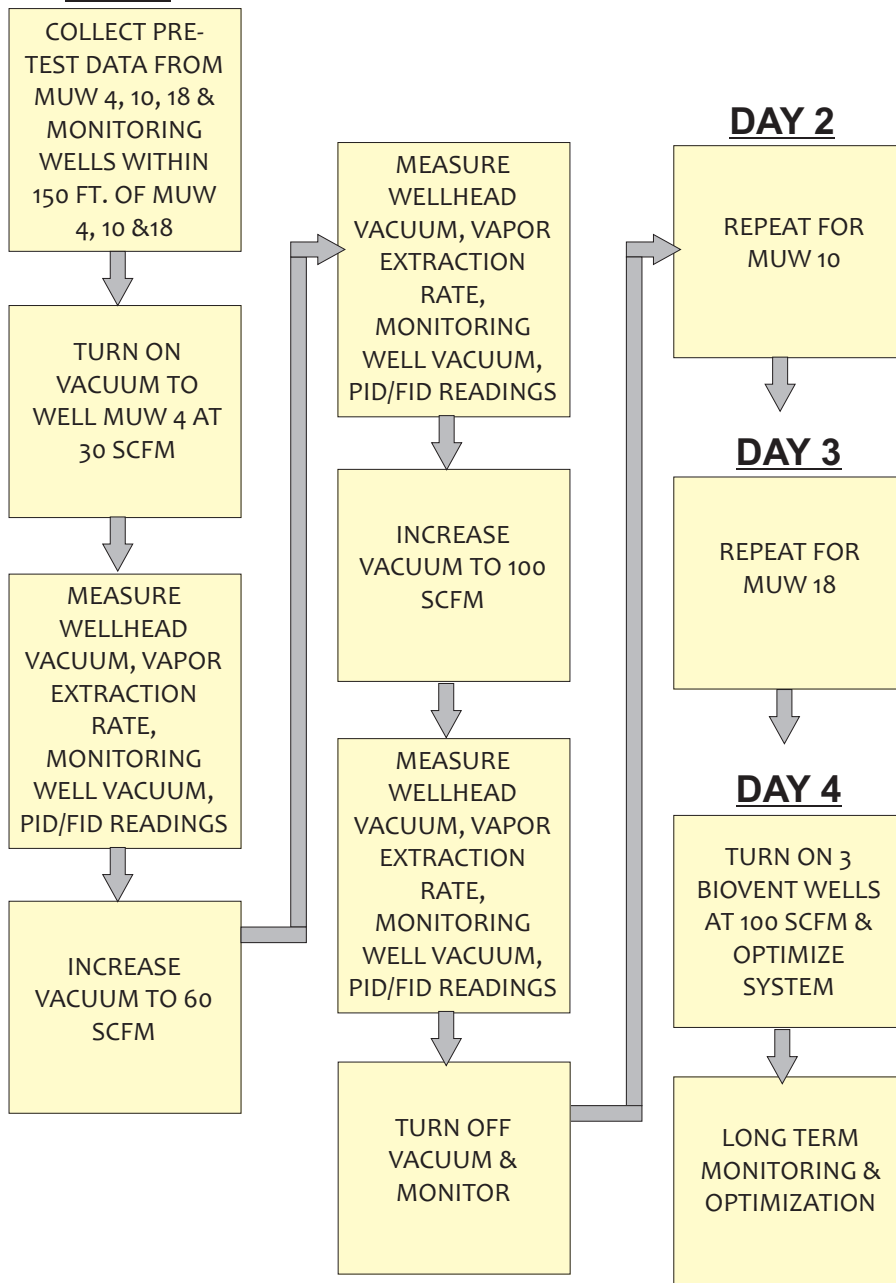


Main objectives of the groundwater and LNAPL recovery system:

- Remove free LNAPL to the maximum extent practicable
- Maximize LNAPL recovery with minimal water production
- Maintain continuous water levels to minimize invasion of water into LNAPL smear zone

FIGURE 2-1
LNAPL/GW PUMP START-UP

DAY 1



Main objective for the bioventing system:

- Maintain the design radius of influence so that the entire targeted portion of the vadose zone is aerated.

FIGURE 3-1
BIOVENTING SYSTEM START-UP

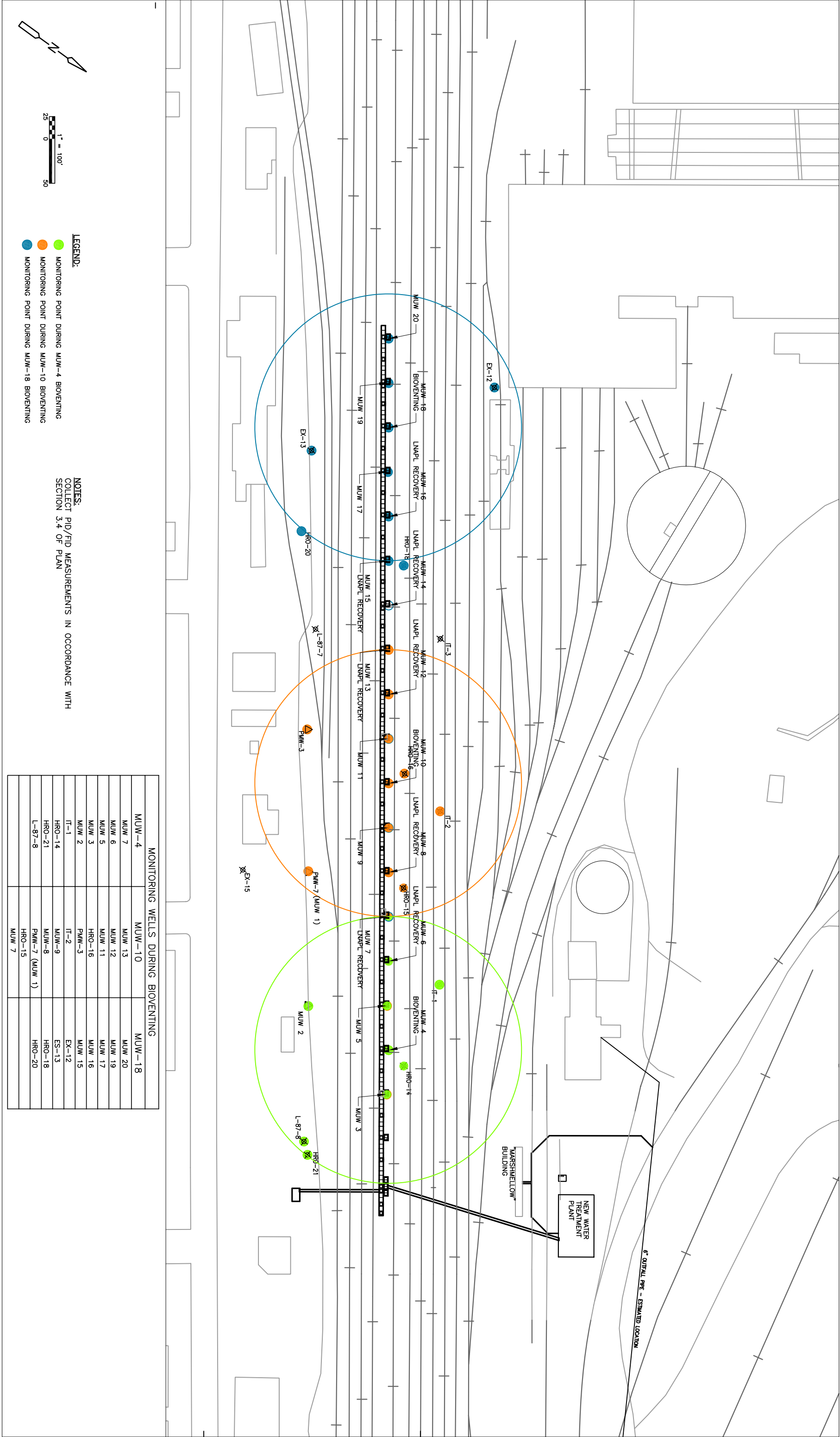


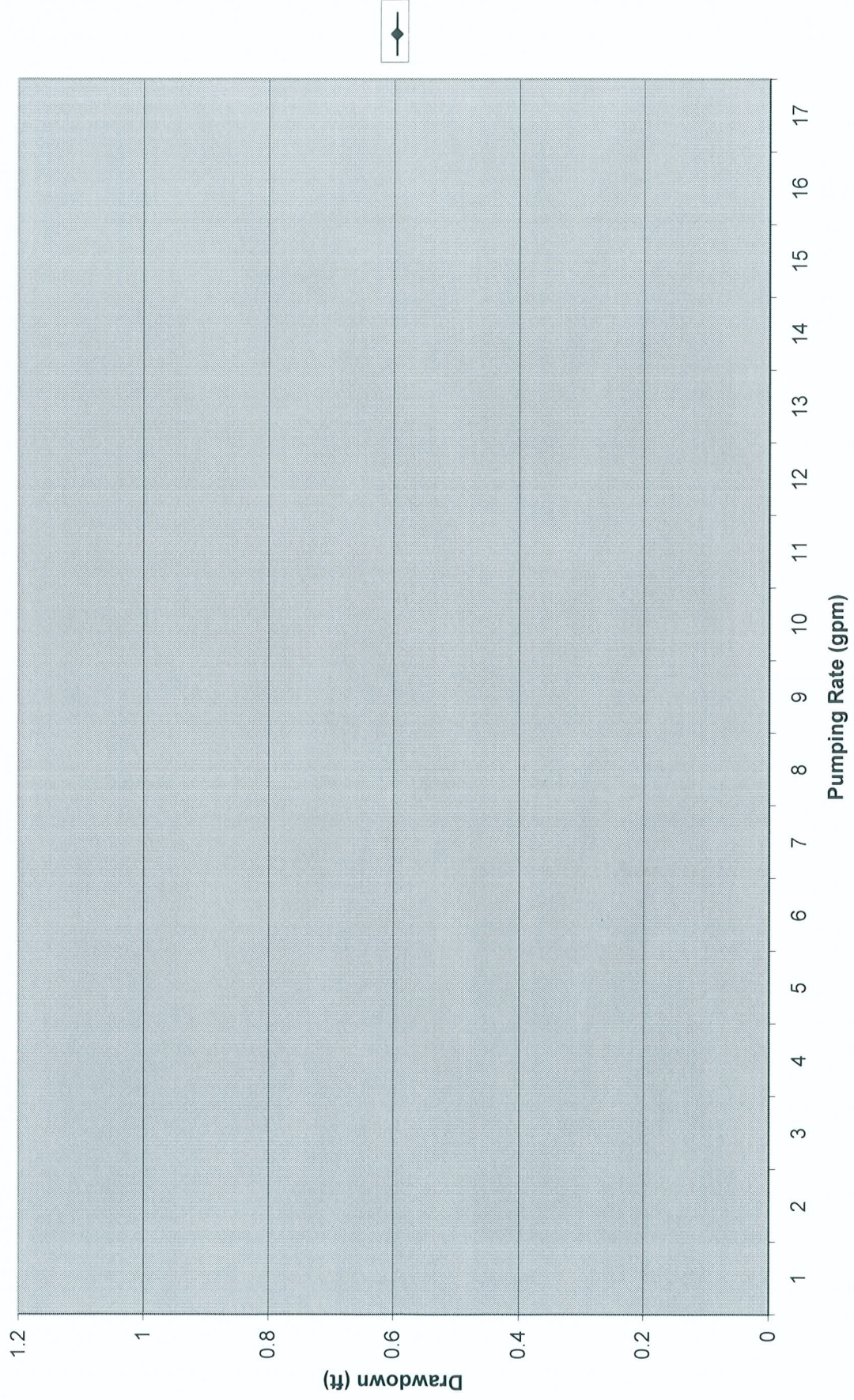
Figure 3-2
Observation Well Locations
for Bioventing Start-up



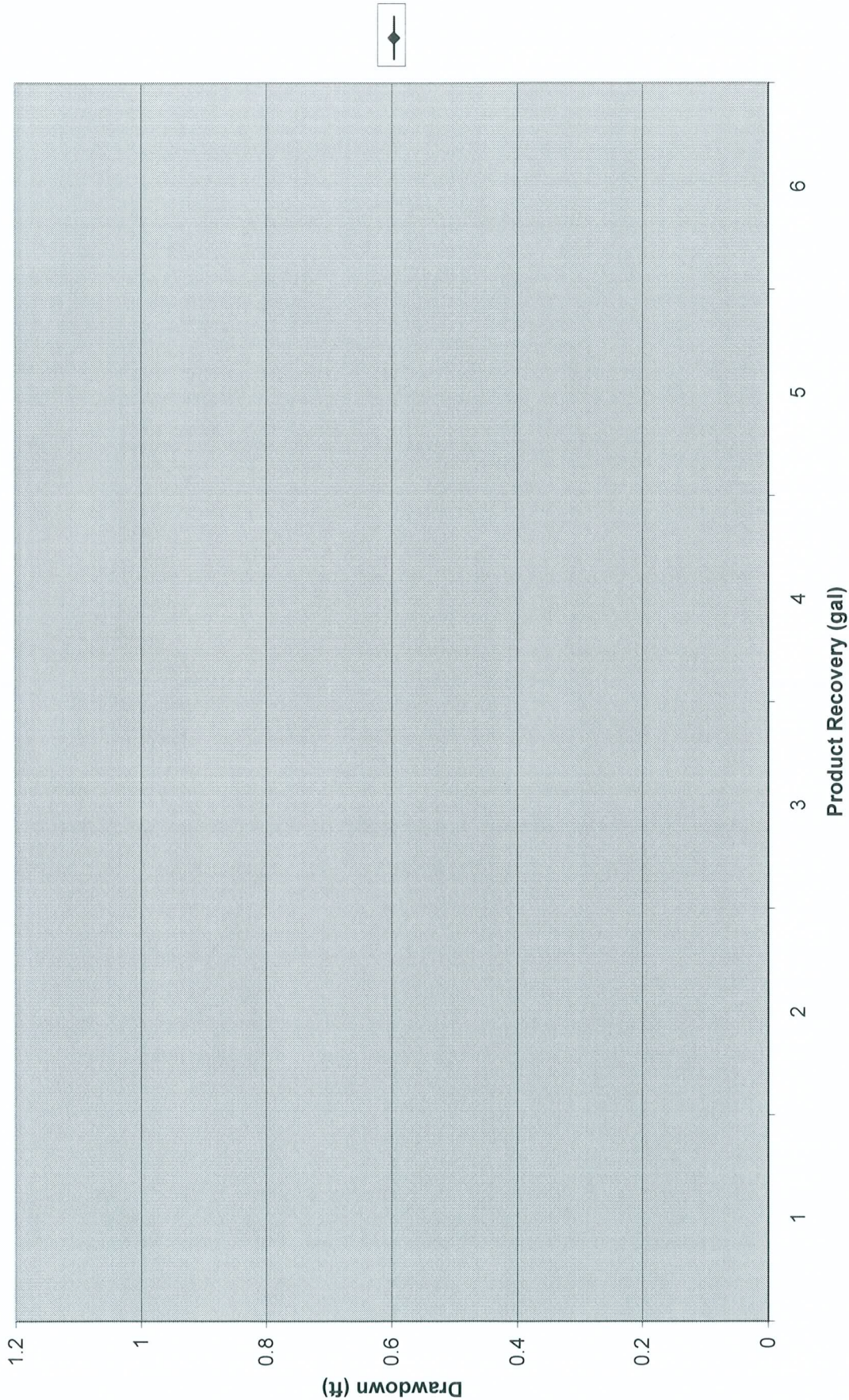
Appendix A

Sample Field Forms

MUW ____ Drawdown vs. Pumping Rate



MUW ____ Drawdown vs. Product Recovery



BNSF Livingston Shop Complex Bioventing System

Well ID:

Well Details (feet)

Measuring Point Elevation	
Top of Screen	
Bottom of Screen	
Top of Smear Zone	
Bottom of Smear Zone	

[illegible]

